Management of Cardiometabolic Risk in Obese Chinese Children and Adolescents: Based on the Postprint of the 2024 Italian Society of Pediatric Endocrinology and Diabetes Position Statement on Cardiometabolic Risk in Obese Children and Adolescents

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Abstract

Childhood and adolescent obesity is a severe global public health problem that not only harms current health but also increases the risk of cardiometabolic diseases in adulthood. In 2024, the Italian Society of Pediatric Endocrinology and Diabetes published a position paper titled "Cardiometabolic Risk in Obese Children and Adolescents," providing important guidance based on the latest evidence for the assessment and management of cardiometabolic risk in obese children and adolescents. This article aims to interpret the core content of this document to provide references and recommendations for the management of cardiometabolic risk in obese children and adolescents in China.

Full Text

Management of Cardiometabolic Risks in Obese Children and Adolescents in China: Based on the 2024 Italian Society of Pediatric Endocrinology and Diabetes Position Paper on Cardiometabolic Risks in Obese Children and Adolescents

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Abstract Childhood and adolescent obesity represents a critical global public health challenge, posing immediate health risks while increasing the likelihood of cardiometabolic diseases in adulthood. In 2024, the Italian Society for Pediatric Endocrinology and Diabetology issued a position paper on Cardiometabolic Risk in Children and Adolescents with Obesity, offering evidence-based guidance for evaluating and managing cardiometabolic risk in this population. This article aims to interpret the core content of this position paper to provide references and recommendations for cardiometabolic risk management among obese children and adolescents in China.

[**Key words**] Pediatric obesity; Adolescent obesity; Cardiometabolic risk; Comorbidity of obesity; Management

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Obesity is a chronic metabolic disease caused by multiple factors, characterized by increased volume and number of adipocytes leading to abnormally elevated body fat percentage and excessive fat deposition in certain local tissues. As an independent disease, obesity also promotes the development of various chronic conditions, including type 2 diabetes mellitus (T2DM), cardiovascular diseases, and osteoarticular disorders. The global prevalence of obesity presents a severe public health crisis, with childhood and adolescent obesity emerging as a particularly urgent worldwide challenge. Over the past decade, childhood and adolescent obesity has shown a concerning rapid upward trend globally [1]. According to a 2019 Italian report, 20.4% of children were overweight, 9.4% were obese, and 2.4% had severe obesity [2]. A 2017–2019 study of 201,098 Chinese children and adolescents aged 3–18 years revealed an overall obesity prevalence of 8.9% [3]. Obesity not only affects children' s current health but also increases their risk of cardiovascular and metabolic diseases in adulthood, with early-onset obesity leading to prolonged exposure to cardiometabolic risk factors (CMRFs).

In response to this challenge, the "Childhood Obesity CMRFs Study Group" of

the Italian Society of Pediatric Endocrinology and Diabetology published a position paper in 2024 titled "Cardiometabolic Risk in Children and Adolescents with Obesity"[4] (hereinafter referred to as the "Position Paper"), which provides evidence-based guidance for assessing CMRFs in obese children and adolescents. Currently, China lacks corresponding guidelines or consensus documents that systematically address cardiometabolic risk (CMR) in obese children and adolescents. Therefore, this study aims to interpret the core elements of this Position Paper and integrate them with relevant Chinese guidelines to provide clinical references and recommendations for managing CMR in Chinese children and adolescents. The interpretation team comprised experts in cardiology, pediatrics, general practice, and evidence-based methodology, with no conflicts of interest with the original guideline development team.

1 Diagnosis of Obesity and CMR

Obesity is a condition of excessive adipose tissue closely associated with increased prevalence of CMRFs. Since direct body fat measurement is rarely feasible in clinical practice, the weight-for-length ratio (for children <2 years) or BMI (for those $ $2 years) serves as the most common diagnostic tool rather than actual body fat percentage. Because BMI is strictly age- and sex-dependent, various metrics can be utilized, including BMI Z-scores, BMI percentiles, percentage of the 95th percentile, or percentage of the median BMI. All these indicators correlate significantly with obesity, visceral adiposity, and CMRFs in children and adolescents, with the latter two showing the strongest associations [5]. Stratification by age- and sex-specific BMI percentiles demonstrates that more severe obesity categories correspond to higher cardiometabolic risk prevalence. Evidence indicates that central obesity in children is increasing more rapidly than BMI [6], necessitating comprehensive assessment tools beyond BMI alone.

Waist circumference can serve as a proxy for abdominal fat content but is limited by the lack of established cutoffs and reference values for children and adolescents. In contrast, waist-to-height ratio (WHtR) shows minimal age variation and allows stratification using a single threshold across ages, making it a convenient tool for screening abdominal obesity and cardiometabolic risk in children. The Position Paper recommends using WHtR $ $0.60 for predicting CMR in obese children and adolescents [4]. Another study based on cross-sectional survey data from 10 countries (including China) identified and validated optimal WHtR thresholds, revealing that European and American populations have relatively higher optimal cutoffs around 0.50, while Asian, African, and South American populations have lower values around 0.46 [7]. China' s "Dietary Guidelines for Obese Children and Adolescents" defines central obesity using age- and sex-specific criteria: WHtR >0.48 for boys aged 6–17 and girls aged 6–9, and WHtR >0.46 for girls aged 10–17 [8]. The Position Paper emphasizes that BMI is crucial for screening overweight, obesity, and severe obesity in children over 5 years and for stratifying CMR, while WHtR provides additional

support when CMR is suspected. For obese adolescents, combining BMI with WHtR enables monitoring of changes in both overall and abdominal adiposity during weight management programs. The diagnostic criteria for obesity and cardiometabolic risk factors are summarized in Table 1 .

2 Early Screening and Intervention for CMRFs

Comprehensive assessment of children and adolescents enables early identification of obesity-related CMRFs, including hypertension, dyslipidemia, prediabetes/T2DM, metabolic dysfunction-associated steatotic liver disease (MASLD), polycystic ovary syndrome (PCOS), obstructive sleep apnea (OSA), reduced renal function, and physical inactivity. Early screening, diagnosis, and intervention recommendations are summarized in Table 2 .

2.1 Hypertension

Hypertension is common among overweight/obese children, with prevalence rates of 5.0% and 15.3% in overweight and obese children, respectively, compared to 1.9% in normal-weight children [9]. Blood pressure screening is recommended for all overweight/obese children starting at age 2 years and should be repeated at each clinical visit. While multiple guidelines recommend confirming hypertension at three different time points, the Position Paper acknowledges potential dropout risks and instead recommends following the European Society of Cardiology consensus [10]: a second blood pressure measurement should be obtained 2–3 weeks after the initial elevated reading to confirm hypertension. Ambulatory blood pressure monitoring has limited clinical application due to the lack of pediatric standards. The Position Paper endorses the European Society of Cardiology consensus for diagnosing hypertension in overweight/obese children and adolescents [10], using blood pressure percentiles stratified by sex, age, and height: elevated blood pressure (90th–<95th percentile), stage 1 hypertension ($ 95*thpercentile*), *andstage*2*hypertension*($95th percentile + 12 mmHg) (Table 2). Confirmation requires two measurements (within 2–3 weeks). Upon initial diagnosis, echocardiography should be performed to assess left ventricular hypertrophy as a marker of target organ damage, which informs decisions regarding pharmacotherapy and subsequent monitoring strategies. The optimal treatment for elevated blood pressure or hypertension in obese children and adolescents corresponds to multidisciplinary obesity management, with lifestyle intervention as the foundation, including low-calorie diets, sodium reduction, decreased screen time, and increased moderate-to-vigorous physical activity. If hypertension persists after 6 months, pharmacological therapy with pediatric-approved agents may be initiated in cases of cardiac/renal damage or failed non-pharmacological treatment. For stage 2 hypertension, treatment should commence immediately or referral to a specialist is warranted. Suitable antihypertensive medications for children include angiotensin-converting enzyme inhibitors (ACEI), angiotensin receptor blockers (ARB), and dihydropyridine calcium channel blockers [10–11]. Diuretics or beta-blockers are not recom-

mended except in specific circumstances.

2.2 Dyslipidemia

The association between childhood obesity and dyslipidemia persists into adulthood and can predict fatal and non-fatal cardiovascular events. Research has established close links between visceral and ectopic fat accumulation and atherogenic dyslipidemia [4]. The optimal age to initiate dyslipidemia screening remains controversial. The Position Paper recommends lipid screening for obese children starting at age 6 years, which may be advanced to age 2 years in those with a family history of cardiovascular disease or high-risk conditions [12–13]. Dyslipidemia includes elevated serum triglycerides and low-density lipoprotein cholesterol, along with reduced high-density lipoprotein cholesterol levels. The diagnostic criteria from the Position Paper are presented in Table 1, which align with Chinese reference standards for dyslipidemia in children and adolescents [14]. Notably, triglyceride cutoffs vary by age (with 10 years as the cutoff point) and differ from adult values (1.7 mmol/L). Obesity-related dyslipidemia is typically managed through dietary and lifestyle interventions, such as controlling total fat intake to 30% of total energy, with saturated fat at 8%–10%, unsaturated fat at 20%, cholesterol <300 mg/day, avoidance of trans fats, and increased high-fiber intake. If dyslipidemia persists, further restrictions are recommended: total fat 25%–30%, saturated fat $ $7%, and cholesterol <200 mg/day [4]. Chinese dyslipidemia management guidelines emphasize that dietary interventions must ensure adequate nutrition to support normal growth and development while recommending at least 1 hour of moderate-to-high-intensity physical activity daily and limiting sedentary time to 2 hours [14]. For overweight/obese children with familial hypercholesterolemia (characterized by markedly elevated low-density lipoprotein cholesterol), pharmacological therapy may be required in addition to dietary and lifestyle modifications.

2.3 Prediabetes/T2DM

Obese children and adolescents face a 13-fold higher risk of diabetes (1.3% prevalence) and nearly threefold higher risk of prediabetes (17.0% prevalence) compared to normal-weight peers, with risks increasing proportionally to BMI [15]. The Position Paper recommends that obese children undergo fasting glucose and glycosylated hemoglobin (HbA1c) assessment starting at age 6 years [12]. For overweight/obese children aged $ $10 years or those who have entered puberty with additional risk factors (first- or second-degree relatives with T2DM, maternal history of diabetes or gestational diabetes, high-risk ethnicity, insulin resistance-related signs such as acanthosis nigricans, hypertension, dyslipidemia, PCOS, or small-for-gestational-age birth), oral glucose tolerance test (OGTT) and HbA1c should be performed (Table 2). Lifestyle intervention forms the cornerstone of prediabetes/T2DM management. For adolescents with prediabetes, all guidelines recommend healthy lifestyle adoption, individualized dietary plans appropriate for age and BMI, replacement of juices and sugary drinks with wa-

ter, and regular physical activity (1 hour of moderate/vigorous exercise daily, with bone and muscle training $ $3 times/week) [4].

For T2DM, pharmacological therapy should be combined with lifestyle interventions based on the severity of metabolic impairment [16]. The target HbA1c should be <7%. Metformin monotherapy may be titrated up to 2 g/day (if HbA1c <8.5%) or combined with subcutaneous basal insulin 0.25–0.5 $\mathrm{U \cdot kg^{-1} \cdot d^{-1}}$ (if HbA1c >8.5%). Intravenous insulin is indicated for ketosis, ketoacidosis, or hyperosmolar states [16]. Approximately 90% of patients on metformin + insulin can discontinue insulin within 2–6 weeks. If HbA1c remains uncontrolled, a glucagon-like peptide-1 agonist approved for pediatric use may be added to metformin [16]. Patients with HbA1c >9% require subcutaneous insulin in addition to maximal-dose metformin and glucagon-like peptide-1 agonists/other agents, possibly including prandial insulin [16]. Patients using insulin or sulfonylureas need close glucose monitoring [12]. HbA1c should be checked every 3 months, with retinopathy and proteinuria screening at diagnosis and annually [16].

2.4 Metabolic Syndrome

Metabolic syndrome represents a cluster of CMRFs, particularly visceral obesity, hypertension, dyslipidemia, and altered glucose metabolism, which increase the risk of cardiovascular disease and T2DM in adulthood. However, due to the lack of consensus on pediatric definitions and diagnostic criteria [17], metabolic syndrome has poor clinical applicability and limited utility in accurately determining clinical significance and practice implications for overweight/obese children and adolescents [18]. Consequently, the Position Paper recommends abandoning the diagnosis of metabolic syndrome and focusing instead on established risk factors. Furthermore, CMRFs should be reassessed at the end of puberty to confirm persistence of risk, with intensified treatment if needed. Increased awareness is needed for obesity-related comorbidities not included in metabolic syndrome definitions, such as fatty liver disease, PCOS, or OSA, which may augment cardiovascular disease risk in overweight/obese youth.

2.5 Fatty Liver Disease

Excessive fat accumulation in the liver is a common feature of childhood obesity. Formerly termed non-alcoholic fatty liver disease, the condition is now preferentially called metabolic dysfunction-associated steatotic liver disease (MASLD) and has become the leading chronic liver disease in pediatrics. Children with MASLD carry a long-term cardiometabolic burden with increased morbidity and mortality in young adulthood [19]. The Position Paper recommends that overweight/obese children aged $ $6 years with elevated serum alanine aminotransferase or presence of other CMRFs should be considered at risk for MASLD and undergo abdominal ultrasound, with hepatic steatosis monitored every 12 months to assess progression to fibrosis. Lifestyle interventions—such as dietary modification, avoidance of sugar-sweetened beverages, moderate-to-high-

intensity physical activity $ $60 minutes daily, and limiting sedentary time—remain the primary treatment. Domestic research confirms that weight-loss interventions significantly improve glucose and lipid metabolism and liver function in obese children and adolescents with non-alcoholic fatty liver disease, with the degree of liver enzyme improvement correlating with the percentage of weight loss [20]. Evidence for dietary supplements (vitamin E, omega-3 fatty acids), prebiotics, and insulin sensitizers remains inconsistent. Currently, no medications are approved, though several promising agents targeting steatosis and fibrosis are under development.

2.6 PCOS

Whether PCOS constitutes a risk factor for cardiovascular disease in adolescence remains unclear, with limited and inconsistent research findings. A systematic review of 23 studies showed that women with PCOS have increased risks of T2DM, hypertension, dyslipidemia, and cerebrovascular disease, suggesting elevated cardiometabolic risk [19], though coronary heart disease events were not increased [19]. Conversely, a retrospective study demonstrated increased risks of myocardial infarction, angina, and revascularization in young women with PCOS, with weight gain and prior T2DM as modifiable risk factors [21]. Hormonal evaluation is recommended for obese adolescents with persistent irregular menstrual cycles and clinical or biochemical signs of hyperandrogenism. The Position Paper emphasizes lifestyle intervention as the fundamental approach to improving metabolic and cardiovascular risk while alleviating PCOS manifestations, with pharmacological therapy to correct hyperandrogenism and menstrual irregularities [22]. Combined oral contraceptives remain the standard treatment for hyperandrogenism, while moderate-to-severe hirsutism requires combined oral contraceptives or anti-androgen agents (spironolactone, finasteride) for at least 6–9 months [22]. Although metformin is off-label, it may be considered in combination with combined oral contraceptives when treatment goals are not achieved [22].

2.7 OSA

Obstructive sleep apnea is characterized by complete or partial upper airway obstruction during sleep, leading to sleep disruption, intermittent hypoxemia, and increased inflammation. The prevalence of OSA in obese children and adolescents (13%–59%) is significantly higher than in healthy peers (1%–4%) [23]. While adult OSA shows independent associations with cardiometabolic disturbances [4], pediatric evidence remains insufficient [24]. Clinical suspicion of OSA is based on symptoms including snoring, restless sleep, daytime sleepiness, headache, attention deficit, and hyperactivity. For obese children with these features, the Pediatric Sleep Questionnaire is recommended for screening [4], with scores $ $0.33 indicating OSA risk. Confirmation requires polysomnography, with diagnosis based on apnea-hypopnea index (AHI) >1 event/hour, moderate OSA defined as 5–10 events/hour, and severe OSA as >10 events/hour

[4]. First-line treatment is adenotonsillectomy, which is recommended for adolescents with AHI >5 events/hour. However, residual OSA after adenotonsillectomy is common in obese patients and may require non-invasive ventilation [4]. Multidisciplinary weight-loss interventions are essential, with bariatric surgery considered for severely obese adolescents with severe OSA (AHI >5 events/hour). Careful perioperative assessment and management are required for severely obese children and adolescents with OSA at high anesthesia risk. OSA reassessment should be conducted using the Pediatric Sleep Questionnaire, with repeat polysomnography every 6 months if residual OSA is suspected [4].

2.8 Physical Inactivity

The World Health Organization recommends at least 1 hour of moderate-to-vigorous physical activity daily for children and adolescents, with sedentary time limited to 2 hours per day [25]. Low physical activity levels and prolonged sedentary behavior are associated with poor dietary habits, contributing to obesity development and persistence. Physical inactivity negatively impacts cardiorespiratory and muscular fitness while exerting adverse effects on obesity, lipid profiles, and cardiometabolic health [26–27]. Exercise interventions should be tailored to address obesity-related physiological and psychological limitations to enhance physical self-esteem, exercise enjoyment, and long-term adherence. Aerobic exercise or combined aerobic and resistance training appears most effective for reducing body fat and controlling obesity-related cardiometabolic complications [28]. The Position Paper recommends exercising 3 times/week, progressively achieving a target of 60 minutes per session. Walking, remote physical activity, and exergaming are considered adjunctive tools against inactivity [29]. Chinese guidelines for physical activity in children and adolescents recommend combined aerobic and resistance exercise, high-intensity interval training, and moderate-intensity aerobic exercise for weight loss, with expert evaluation required before exercise in severely obese youth to prevent joint injury [30].

2.9 Cardiac Issues

Left ventricular hypertrophy is the most common cardiac structural and functional abnormality phenotype in overweight/obese adolescents, with a prevalence of 36.3%–46.6% among overweight/obese Italian youth [31]. The Position Paper advocates diagnosing left ventricular hypertrophy in overweight/obese adolescents using pediatric left ventricular mass index reference values [32] rather than adult cutoffs. Echocardiographic screening is recommended when comorbidities such as hypertension, chronic renal failure, dyslipidemia, T2DM, or MASLD are present. Identifying left ventricular hypertrophy represents a crucial step in cardiovascular risk assessment. Strategies to reduce cardiac damage progression, particularly left ventricular hypertrophy or dysfunction, include lifestyle modifications such as reducing sugar, salt, and lipid intake while increasing physical activity to decrease hemodynamic overload [4].

2.10 Vascular Issues

Research demonstrates that atherosclerotic changes may appear in childhood [33]. Evidence indicates that obese children may initially exhibit signs of endothelial dysfunction, such as impaired flow-mediated vasodilation [34] and increased carotid-radial pulse wave velocity [35], followed by morphological changes like increased carotid intima-media thickness (cIMT). Increased arterial stiffness may serve as an early marker of elevated cardiovascular risk, with carotid-radial pulse wave velocity being the gold standard for assessment. While flow-mediated dilation measurement is an important pathophysiological factor related to vascular reactivity changes, it is less commonly used in clinical practice, whereas cIMT ultrasound measurement is more feasible. Although cIMT has been established as an independent predictor of cardiovascular events in adults, its predictive value in adolescents has not been confirmed in longitudinal studies of cardiovascular outcomes, and it is currently used only as a non-invasive measure of preclinical atherosclerosis in pediatric research, not recommended for routine diagnosis in overweight/obese adolescents. Multi-strategy weight-loss interventions in adults may improve early vascular functional and structural abnormalities [36]. In children, Mediterranean diet and physical activity have been shown to normalize cIMT in obese youth [37], while exercise training improves endothelial function and reduces arterial stiffness in overweight/obese adolescents, particularly when BMI <30 kg/m^2 [38]. Aerobic exercise appears most effective for improving arterial stiffness [38].

2.11 Renal Issues

Obesity-related kidney disease can manifest in childhood and accelerate renal function deterioration as a modifiable risk factor, increasing mortality risk in children with end-stage renal disease [39–40]. Renal disease screening involves measuring microalbuminuria and serum creatinine, with the former being a well-established assessment method and the latter an economical, widely adopted clinical indicator of renal function. Given the adverse impact of obesity on renal function and its prognostic significance, the Position Paper recommends that all overweight/obese children aged $ $6 years undergo microalbuminuria and serum creatinine testing at initial evaluation. If results are abnormal, renal function should be monitored every 6 months; if comorbidities such as hypertension, prediabetes/T2DM, or PCOS are present, monitoring should occur every 3–6 months. Since obesity is a modifiable risk factor for kidney disease, weight-loss strategies (including dietary modification, salt reduction, and increased physical activity) constitute first-line therapy [39–41]. Blood pressure must be strictly controlled below the 90th percentile for age, sex, and height. Evidence for pharmacological interventions in obese children with kidney disease remains limited and inconclusive [4,39,42]. Beyond conventional renoprotective agents (ACEI/ARB), glucagon-like peptide-1 receptor agonists show promise for renal protection through metabolic and anti-inflammatory effects, though data remain variable [4,39,42]. Bariatric surgery has demonstrated positive effects on kidney

disease in severely obese adolescents [42], but its application is limited and long-term outcomes remain uncertain [4].

3 Summary and Implications

Obesity represents a major risk factor for cardiovascular disease in children and adolescents through both direct and indirect mechanisms, necessitating effective monitoring and intervention strategies to reduce cardiovascular morbidity and premature mortality. The Position Paper provides an important reference framework for developing relevant guidelines in China, particularly regarding screening, comorbidity management, and follow-up monitoring of CMRFs in obese children and adolescents. Management of obesity-related CMRFs requires integrated measures to reduce cardiometabolic disturbances, early screening for obesity comorbidities, multidisciplinary treatment, and long-term monitoring. Weight-loss interventions concurrently reduce cardiovascular risk. Comprehensive weight management should combine lifestyle interventions (behavioral modification, diet, exercise), pharmacotherapy, and metabolic/bariatric surgery [43].

Lifestyle intervention is the primary therapeutic approach. While ensuring adequate nutrition for normal growth and development, recommendations include low-calorie diets, reduced intake of high-sodium and high-fat processed foods, decreased saturated fatty acids, avoidance of sugar-sweetened beverages and trans fatty acids, increased dietary fiber, and cultivation of healthy eating habits (regular meals, avoiding screen use during meals) [4,43]. Physical activity should progressively increase to at least 60 minutes of moderate-to-high-intensity exercise daily (combining aerobic and resistance training), achieving $ $3 sessions per week, while limiting screen time/sedentary behavior to $ $2 hours daily [4,43].

Regarding pharmacotherapy, weight-loss medications should not be used in overweight children and adolescents and should be strictly limited in obese youth, considered only when intensive lifestyle interventions fail to achieve weight loss or comorbidity improvement [44]. If BMI-Z score does not decrease by >4% after 12 weeks of medication, weight-loss drugs should be discontinued and the patient re-evaluated [43]. Currently, no weight-loss medications are approved for pediatric use in China [44]. Metabolic/bariatric surgery in children and adolescents should strictly follow surgical indications, with individualized comprehensive assessment of necessity, timing, and procedure type [44]. According to the "Chinese Guidelines for Surgical Treatment of Obesity in Children and Adolescents (2019 Edition)" [45], the main procedures are sleeve gastrectomy and Roux-en-Y gastric bypass, both performed using minimally invasive techniques. Multidisciplinary team management throughout the preoperative, intraoperative, and postoperative phases—including experienced bariatric surgeons, pediatricians, nutritionists, and psychologists—is essential to ensure safety and recovery outcomes. Although surgery effectively controls obesity, long-term risks exist, including potential deficiencies in iron, vitamin B12, and vitamin D, as well as postprandial hypoglycemia and growth retardation. Poor adherence

in children and adolescents makes long-term nutritional supplementation challenging [45], necessitating long-term follow-up, nutritional management, and mental health monitoring to prevent depression, anxiety, and self-esteem issues, thereby improving long-term prognosis and quality of life.

A multidisciplinary collaborative model should be employed, encouraging cooperation among pediatricians, endocrinologists, nutritionists, exercise specialists, family physicians, psychologists, and surgeons to develop individualized intervention plans with continuous psychological support and behavioral modification to ensure adherence. Additionally, traditional Chinese medicine, acupuncture, and massage may be integrated based on syndrome differentiation. Management of obesity-related CMRFs should implement disease-specific strategies, combining pharmacotherapy with lifestyle interventions when necessary while considering benefits for other obesity-related comorbidities. Regular monitoring of comorbidities is essential to evaluate treatment efficacy and optimize management promptly, thereby reducing future cardiovascular risk.

With widespread application of artificial intelligence technology, guideline-based risk prediction, decision support, real-time monitoring, and dynamic feedback systems have become feasible. Machine learning analysis of electronic health records enables precise stratification of cardiometabolic risk and automatic identification of high-risk patients. Personalized intervention plans can be generated and tracked through digital tools (e.g., apps) monitoring dietary behavior, physical activity, and weight changes. Smart wearable devices (e.g., fitness trackers) enable real-time monitoring of blood pressure, heart rate, and activity levels, allowing dynamic adjustment of intervention intensity and content based on real-time data. This approach enhances management precision and effectiveness while providing psychological support through emotional interaction features to improve treatment adherence. Moreover, management should shift upstream, prioritizing prevention over treatment. Multidisciplinary teams should actively participate in screening and managing childhood obesity and related risk factors, promoting healthy dietary and behavioral habits. A "school-family-hospital-community" closed-loop management system should be established under government leadership, strengthening school and family involvement and implementing campus health promotion programs and family-based education on healthy eating and exercise [43].

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